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**PROPOSED KILAUEA MIDDLE EAST RIFT
GEOTHERMAL RESOURCE SUBZONE**

Island of Hawaii

Circular C-114



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DEPARTMENT OF LAND AND NATURAL RESOURCES
Division of Water and Land Development**

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**Honolulu, Hawaii
May 1985**



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Governor

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PREFACE

Pursuant to the Decision and Order (see Appendix A) on the proposed geothermal resource subzone at Kahaualea, Hawaii, rendered by the Board of Land and Natural Resources on December 28, 1984, the Department of Land and Natural Resources has been directed to conduct an assessment of the Kilauea middle east rift zone for possible designation as a geothermal resource subzone.

The objective of this report is to provide information to the Board of Land and Natural Resources so that it may evaluate the geothermal resource and examine potential impacts from geothermal development on the area in and adjacent to the Wao Kele 'O Puna Natural Area Reserve.

This report identifies the Kilauea middle east rift, Island of Hawaii, as a potential geothermal resource subzone and summarizes the results of a statewide assessment conducted by the staff of the Division of Water and Land Development with participation of an interagency technical committee; federal, state, and county agencies; private industry; and the general public.

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INTRODUCTION

Act 296, SLH 1983, mandates the Board of Land and Natural Resources to designate geothermal resource subzones in the State of Hawaii. The purpose of this Act is to provide a policy that will assist in the location of geothermal resource development in areas of lowest potential environmental impacts. Once geothermal resource subzones are established, all geothermal development activities may be conducted only in these designated subzones.

During the period of December 12-20, 1984, the Board of Land and Natural Resources conducted a contested case hearing on the proposal to subzone a portion of the Kilauea upper east rift zone, Island of Hawaii. Parties to those hearings submitted proposed findings of fact and conclusions of law to the Board concerning the designation of all or any portion of the proposed Kilauea Upper East Rift geothermal resource subzone.

On December 28, 1984, the Board of Land and Natural Resources rendered a Decision and Order which approved the designation of approximately 800 acres, described in the Board's earlier Decision and Order on the Kahaualea Conservation District Use Application issued on February 25, 1983.

One condition set forth in the Board's Decision and Order formally requests the Estate of James Campbell to investigate and consider a land exchange involving State-owned lands in the Kilauea Middle east rift zone and Campbell Estate's lands at Kahaualea.

The Board of Land and Natural Resources also directed the Department of Land and Natural Resources to evaluate the area of the Kilauea Middle East Rift in and adjacent to the Wao Kele 'O Puna Natural Area Reserve as a potential geothermal resource subzone.

This report represents the assessment of the potential geothermal resource areas located between the western boundary of the Kamaili geothermal subzone and the eastern boundary of Campbell Estate's land at Kahaualea, Hawaii.

ASSESSMENT OF GEOTHERMAL RESOURCE

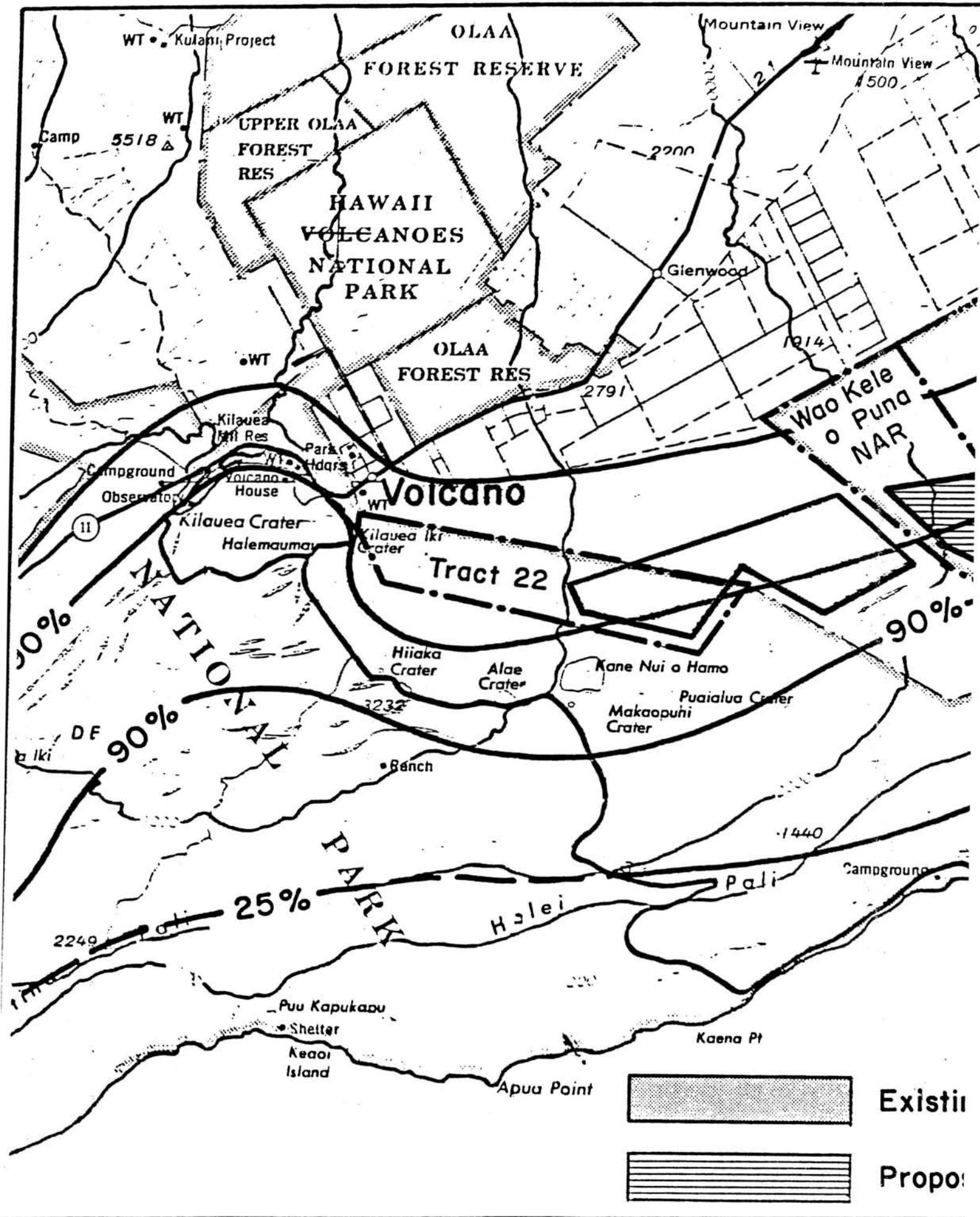
A Geothermal Resources Technical Committee was formed by the Department of Land and Natural Resources consisting of experts in the field of geothermal resources in Hawaii. The Technical Committee members met in a series of meetings and made a statewide, county-by-county assessment based on currently available geotechnical data.

The consensus of the Technical Committee was that present day technology requires a geothermal resource to have a temperature greater than 125°C at a depth of less than 3 km to be feasible for production of electrical energy.

The assessment of geothermal resource potential was based on a qualitative interpretation of regional surveys based on the following types of data: groundwater temperature, geologic age, geochemistry, resistivity, infrared, seismic, magnetics, gravity, self-potential, and exploratory drilling.

In assessing the potential geothermal resource areas, the committee utilized probability ranges, in that probabilities would be more accurate than other subjective wording.

Currently available geotechnical data indicated the presence of a geothermal resource along the entire Kilauea East Rift Zone. The evaluation of this data indicated that the potential for a geothermal resource on this rift zone was greater than 90% through its entire length. This finding was based on the following data: extensive eruption and intrusive activity along the entire length of the rift during the last millennium; an aeromagnetic anomaly associated with the rift showing that temperatures in excess of 500°C were present at shallow depths in the rift; resistivity anomalies indicating shallow high temperature ground water; the presence of high temperature shallow wells within and adjacent to the rift; and a productive deep geothermal well. The evaluation of the rift zone suggested a greater than 90% probability for a resource along the presently visible trace of the rift with a gradual decline in probability out to the extent of the aeromagnetic anomaly. Oral and written testimony subsequent to the



completion of the technical committee's assessment brought out the following additional considerations:

- (1) An interpretation of the aeromagnetic data by one of the technical committee members suggested that Curie temperatures greater than 500°C may be present at depths of 2-3 kilometers out to the limits of the 25% probability line originally drawn.
- (2) An interpretation of the available geologic and gravity data suggests that the rift zone has migrated southward to its present active location and is much broader in the northward direction than the present surface expression.

Therefore, the Kilauea middle east rift zone, located between the western boundary of the Kamaili geothermal resource subzone and the eastern boundary of Campbell Estate's land at Kahaualea is estimated at having a greater than 90% chance of finding a high temperature (greater than 125°C) resource at depths less than 3 km.

The potential high temperature resource area of the Kilauea Middle East Rift is denoted by the 90% probability lines indicated on Figure 1. The area shown between the 90% and 25% probability lines represents decreasing geothermal resource potential.

The conclusions of the Technical Committee demonstrated that no single geothermal exploration technique, except for exploratory drilling, is capable of positively identifying a subsurface geothermal system; instead it is based on several methods resulting in an estimate of geothermal potential for a given area.

The geothermal resource assessment of the Kilauea middle east rift is the first phase of the overall evaluation process prior to any subzone designation. Subsequent analysis of social, economic, environmental, and hazard impacts are discussed in this report on this area having significant potential for the production of electricity from geothermal energy.

SOCIAL IMPACTS

This section on the social impact analysis of the geothermal resource area along the Kilauea middle east rift gives emphasis to people's perceptions, attitudes, and concerns regarding geothermal resource development activities.

The assessment of social impacts was based on currently available public information concerning health, noise, lifestyle, culture, community setting, aesthetics and community input.

Health Aspects

The health aspects of geothermal resource development involve primarily the effects of chemical, particulate, and trace element emissions on the physical environment and on residents in the vicinity. Hydrogen sulfide (H_2S) is the most significant gas found in geothermal emissions.

The study, "Evaluation of BACT for Air Quality Impact of Potential Geothermal Development in Hawaii," January, 1984, prepared for the U.S. Environmental Protection Agency by Dames & Moore on the Best Available Control Technology (BACT) for emission abatement was utilized in the assessment. H_2S , particulate and trace element emission rates were developed from data gathered at HGP-A and assumed the emission controls described in the "BACT" report. EPA-developed air dispersion models were then used to estimate the impact of these pollutant emissions on ambient air quality.

The technology for abatement of hydrogen sulfide emissions from proposed facilities to acceptable levels is available and the "BACT" study recommends the Stretford system as the primary on-line abatement. This system can remove over 99% of the H_2S contained in the non-condensable gases.

For control of noise and H_2S emissions during well flow testing, a caustic injection and rock muffler system was installed in 1979. This system is now used for standby venting during periodic plant maintenance. The two-phase fluid is exhausted to the atmosphere

through a hooded rock muffler and liquid is collected in the muffler basin and pumped to the percolation pond while the steam rises through the rock layer and is directed out the hood stack. Tests of this system have shown 90-95 percent H₂S removal.

A geothermal plant is expected to be on-line 90-95% of the time. Contingency abatement-systems can be utilized in the event the plant is "down" for maintenance. If maintenance is required, the geothermal steam can be re-routed directly into the condenser utilizing the primary abatement systems. If the primary abatement system is not operational, a secondary abatement system such as NaOH (caustic soda) scrubbing can be used in combination with a rock muffler to achieve 92-95% H₂S removal.

"The Puna Community Survey", prepared in 1982 by SMS, Inc. for the State Department of Planning and Economic Development and the Hawaii County Department of Planning, reported that only one-fifth of the total survey respondents felt that they had been affected by the geothermal wells in Puna, on the Hawaii Island.

In the "Puna Speaks" case, where HGP-A shutdown was requested by some Puna residents, the U.S. District Court Judge ruled that the plaintiffs did not prove their case in suit as no causation was established between the well emissions and alleged maladies.

Noise Aspects

The impact and intrusiveness of noise from geothermal development activities on the surrounding environs is dependent on the meteorological conditions; the intensity of the noise source; the sound propagation conditions existing between the source and listener; the ambient or background noise at the receptor; and the activity at the receptor area at the time of the noise event.

As any geothermal project progresses, noise propagation information will be obtained and will serve as guidance for the design of noise mitigation measures required of the power plants, particularly for power plants located close to noise sensitive residential and park areas.

Although noise levels associated with geothermal energy development and operation are comparable with those of industrial or electrical plants of similar size, plant construction and operation in a quiet rural area are a potential noise factor which can be controlled and monitored.

The source of noise impact from the proposed geothermal resource subzone would arise from (a) construction of roads, pipelines, and buildings; (b) geothermal well-drilling and testing or venting; and (c) geothermal power plant operations.

During the initial phases of field development, persons in the immediate vicinity of a geothermal site may be exposed to noise levels varying from 40 to 125 decibels, depending upon the distance from the well site.

Noise generated by construction activity will involve the use of standard construction equipment such as local bulldozers, trucks, and graders operating in the same manner, and over a limited time period as any other typical project. No unusual noise events of long duration are involved.

Within 100 feet of the drill rig, noise varies from 60 to 98 decibels with muffler. Initial venting noise varies from 90 to 125 decibels which may be mitigated using a stack pipe insulator or cyclone muffler. Periodic operational venting noise is about 50 decibels using a pumice filled muffler.

The use of noise abatement procedures during venting, such as portable or in-place rock mufflers, can reduce noise levels from the drill site. Noise levels for proposed power plants are expected to be low and should result in slightly audible or inaudible levels at most receptor sites.

Power plant buildings and barriers can be designed to optimize the orientation and degree of closure to contain noises from the turbine, generator and transformers. Cooling towers have not proven to be dominant noise sources in geothermal plants. Taking all major noise sources into account, the continuous noise level of 75 dBA at 100 feet is considered readily achievable for power plants.

Ambient or background noise refers to the noise levels which presently exist in the environs of the proposed geothermal resource subzone and at locations where people reside, play or work and sometimes is produced by the people themselves. The existing exterior ambient noise levels at residences in the environs of the proposed geothermal operations are dictated largely by the sounds of nature and by traffic on local roads.

Ambient noise levels are often expressed as day-night noise levels (Ldn) where a 10 dB reduction is given for noise levels during the night time period between 7:00 p.m. to 7:00 a.m. The long-range strategies of the Environmental Protection Agency (EPA) are to achieve a goal of 55 dBA (45 dBA nighttime) which will ensure protection of public health and welfare from all adverse effects of noise based on present knowledge.

The EPA "Protection Noise Level" document's recommended levels are levels defined by a negotiated scientific consensus that was developed without concern for economic and technological feasibility, is intentionally conservative to protect the most sensitive portion of the American population, and includes an additional margin of safety. The levels should be viewed as levels below which there is no reason to suspect that the general population will be at risk from any of the identified effects of noise.

In May of 1981, the County of Hawaii Planning Department issued a set of "Geothermal Noise Level Guidelines" to provide proper control and monitoring of geothermal-related noise impacts with stricter standards than those prevailing for Oahu, based on lower existing ambient noise levels for the Island of Hawaii.

Geothermal development activities have been required to comply with the Geothermal Noise Level Guidelines of the Hawaii County Planning Department ("Guidelines"). The "Guidelines" specify that the "acceptable geothermal noise guidelines should be at a level which reasonably assumes that the Environmental Protection Agency and U.S. Department of Housing and Urban Development criteria for acceptable indoor noise levels can be met" and that the sound level measurements

should take place at the affected residential receptors that may be impacted by the geothermal operation.

For example, the design standard for the HGP-A Wellhead Generator Project specifies that the noise level one-half mile from the well site must be no greater than 65 decibels. Construction of a rock muffler at the facility has reduced noise levels to about 44 decibels at the fence line of the project.

The type of housing normally found near the vicinity of the proposed geothermal resource subzone, will result in noise reduction from outside to inside of at least 15 dB. Thus, an outside noise level of 45 dBA will reduce to an inside level of 30 dBA or less, which is less than the EPA's 32 dBA level for sleep modification.

Lifestyle, Culture, and Community Setting

The lifestyle, culture and community setting or atmosphere of an area are very much inter-related and represent a major concern in terms of the effects of any introduced changes, especially when the changes may be in the direction of industrial development in a relatively rural setting.

The Puna area has the most information and the input to-date on these aspects related to geothermal development and may be applicable to other localities. Each community, however, will have its own unique background and perceptions and goals. Each community should in the process of considering geothermal resource development contribute its own input into the assessments.

In April 1980, 11,751 persons were living in Puna which constituted roughly 13 percent of the Big Island's population. The Puna district is the third largest in terms of size and population. Puna's population density is 27 persons per square mile versus 22.8 persons per square mile for the County of Hawaii as a whole. Within the Puna District, roughly 20 percent (2,238) of the residents were living in the towns of Keaau, Mountain View, and Pahoa.

One of the survey questions discussed in the "Assessment of Geothermal Development Impact on Aboriginal Hawaiians" by the Puna

Hui Ohana, regarding Community attitudes toward geothermal development asked respondents how they felt about the quality of life in Puna at the present time. The large majority responded that they were happy with the present quality of life in Puna, while only 9.5% were unhappy and 8.6% were neither happy nor unhappy.

Property in the middle east rift zone is owned by two large area landowners, the State of Hawaii and Campbell Estate. Smaller holdings owned by various individuals are found along the coast and in agricultural zoned areas in the Kalapana and Kaimu areas at the makai boundary of the rift zone.

The small magnitude of change in lifestyle and social interaction that may be brought about by new residents may be a small part of the lifestyle, culture and community and traffic changes already taking place in the area as a result of the influx of new residents in recent years.

The practice of religion by modern Hawaiians has been sustained and continuous over time. The belief and worship of the volcano goddess Pele has become an integral part of Hawaiian culture. Native Hawaiian Practitioners consider the lands adjacent to Kilauea Crater (defined by some people to be contained within a six mile radius) as sacred and is regarded as the home of Pele and her supernatural associates.

The summit area of Kilauea volcano which includes the mauka portion of Kahaualea is considered sacred to worshippers of the goddess Pele and is used actively in the practice of traditional Hawaiian religion.

Certain native Hawaiian practitioners believe that geothermal development threatens their belief in Pele and that Pele in her manifestation as steam cannot be sold for monetary gains. They are concerned about traditional Hawaiian beliefs regarding the uses of geothermal steam, suggesting that Madam Pele, the Hawaiian fire goddess, would be offended by geothermal drilling.

Prehistoric cultural activities and features such as foot trails, upland taro patches and planting areas, a pulu factory, and other

sites have been reported in the area adjacent to the proposed subzone. As geothermal development occurs each new increment of land area should be archaeologically surveyed by a qualified archaeologist after specific boundaries are determined and before land clearing begins. If archaeological sites are found, they should be described and assessed as to significance, and measures taken to ensure avoidance or mitigation of potential impacts from geothermal developments.

The recognition and use of geothermal energy in Hawaii has been recorded well back into the history of the Hawaiian Islands. Explorers identified numerous fumaroles and thermal features on Kilauea and Mauna Loa volcanoes as early as 1827. Early Hawaiians used the steam emanating from fissures along the rift zone for cooking and geothermally heated water ponds for bathing.

Aesthetics

"The Puna Community Survey" by SMS Research Inc. reported that of the negative impacts perceived relating to the geothermal development, 5% felt that it "looks bad". The area respondents with the greatest percentage were Keaau residents, with 25% of the factors mentioned being under the category of negative appearance.

In some areas with potential geothermal resource development, the plant installation may be relatively unobtrusive--where scenic view corridors are not damaged in the eye of nearby or medium-distanced residents and visitors--however, consideration of aesthetic aspects should include careful siting, tasteful design, and effective landscaping.

Techniques of preserving aesthetic aspects of the landscape and natural vistas include attractive design, painting of structures, towers and plants with colors to blend in with the natural setting.

Exploratory drill rigs, including a platform, may reach to heights of 149 feet. Rigs may be visible above the tree line in the exploratory area only during the period of exploration.

It is possible that the moist warm air from the cooling towers will condense as it rises under certain atmospheric conditions to form a

small cloud mass similar to that often observed near cracks and puu's along the remote part of the Kilauea east rift zone east of Mauna Ulu under the same conditions. During normal atmospheric conditions, little to no visible vapors are expected from the cooling towers.

Estimates of visual impact can be accomplished by preparing an area wide terrain analysis to determine locations outside the project area from which drilling rigs, powerlines, power plant facilities, etc., can be seen.

A similar terrain analysis should be included in environmental impact assessments for the development of specific sites within a geothermal resource subzone during the subsequent permitting process.

Community Input

Various channels and methods of community input are involved in the preliminary as well as future process of geothermal resource development, evaluation and actualization, such as the community surveys by the Puna Hui Ohana and by SMS Research, Inc.

Throughout the process, from the enactment of Act 296, to the Proposal for Designating Geothermal Resources Subzones by the BLNR, public comments and participation has been invited from various interested parties to assist the Department and the Board.

Public informational meetings were held by the State Department of Land and Natural Resources on March 12 and 13, 1985 on the island of Hawaii. The first series of meetings were to report the most likely locations of geothermal resources; the second series focusing on the identification of impact issues.

To ensure full public participation, the time, place and purpose of these meetings were announced in newspaper publications, radio announcements and letter invitations. The objective of these meetings was to open lines of communication between the public and the Department of Land and Natural Resources.

Other sources of community input utilized in the assessment included the planning processes, goals, objectives and development

policies formulated and adopted in community plans that become a part of the County General Plans and the State General Plan, as well as policies brought forth by representatives of people and communities in the State Legislature.

Ownership of Geothermal Resources

Mineral rights to geothermal resources in Hawaii is somewhat uncertain. Although a 1974 State statute defines geothermal resource as a "mineral", there remains questions as to whether pre-1974 mineral reservations expressed in grants apply to geothermal resources. In addition, grants issued between 1900 and 1955 failed to include the standard provision reserving all mineral rights to the State. Therefore, another problem is presented as to whether mineral reservations are to be implied in grants which contain no express reservation.

These issues will not be definitively answered until they are litigated in court or an agreement is reached between the State and private parties involved.

POTENTIAL ECONOMIC BENEFITS TO BE DERIVED FROM GEOTHERMAL DEVELOPMENT AND RELATED INDUSTRIES

Need for Indigenous Resources to Supply Energy Requirements

Petroleum provides over 90% of Hawaii's total energy needs. About \$1.5 billion annually flows out of the State's economy to finance our petroleum demand. This dependency renders Hawaii vulnerable to disruptions in the supply of foreign oil. Although the present world supply of oil is plentiful with prices declining, this oil situation is politically volatile and uncertain in the long run. Present oil reserves within the State could last about 30 days. Oil from the national Strategic Petroleum Reserve in Texas and Louisiana would take about 60 days to arrive in Hawaii, possibly having major local economic

consequences. About one-third of our oil imports are required for producing electricity. This economic backdrop emphasizes the State objective of energy self-sufficiency. The Department of Planning and Economic Development believes that geothermal energy has the largest near-term potential to provide an indigenous base-load electric supply and offers some measure of self-sufficiency.

Current peak electrical demand on the Big Island is about 100 MW, with nighttime base demand of about 40 MW. An annual load growth of about 1% is expected. Electrical generation capacity on the Big Island is about 130 MW (including reserve capacity), with about 60% generated by oil, 33% by biomass, 5% by hydro, and 2% by geothermal. Biomass' significant contribution may change as sugar production (bagasse availability) is being reduced; however, this may be offset by woodchipping. The Hawaiian Electric Light Company is seeking proposals from geothermal developers to provide future generation capacity.

Employment and Revenue Generated by Geothermal Development

Development of geothermal resources would provide numerous job opportunities during the construction, maintenance, and operation of the roads, wells, and power generation facilities. The total number of employment opportunities will depend on specific development proposals. However, most jobs would be temporary construction jobs.

If we assume 25 project employees, direct wages may be about \$560,000 annually, having a multiplier effect totalling an estimated \$1.3 million. This would result in some impact on the state and county economy, but not a significant impact. A greater potential for permanent jobs for local residents may be provided by direct use applications of geothermal heat.

Various sources of public revenue may result from a geothermal facility, including property tax, fuel tax, general excise tax, corporate and personal income tax, and possibly royalty income.

Direct Use Applications

Direct use of geothermal heat should offer local residents many economic opportunities. The warm water effluent from a geothermal electric facility can provide an inexpensive source of process heat for various uses.

Some agricultural activities which can be supported by geothermal heat include: sugarcane processing, drying and dehydration of fruits and fish, fruit and juice canning, production of livestock feed from fodder, freeze drying of food and coffee, aquaculture and fishmeal production, refrigeration and ice making, soil sterilization, and fruit sterilization by dipping in hot water.

Industrial applications of direct geothermal heat may include extraction of potentially marketable minerals, such as silica or sulfur from geothermal fluids, production of cement building slabs, and production of liquid combustion fuels from biomass, e.g. bagasse or other agricultural by-products.

The Puna Geothermal Research Facility will explore the feasibility of some of the above direct use applications in Hawaii. The research facility, scheduled to be in operation in late 1985, is state funded and administered by the Hawaii Natural Energy Institute. It will be located adjacent to the HGP-A geothermal electric plant.

Other direct uses include hot geothermal mineral water spas which have proved to be of major commercial value in producing tourist revenue in Japan, Europe, U.S.S.R., and mainland United States, where millions visit these facilities annually. In places where fresh water is scarce, geothermal heat can be used to distill fresh water from saline water.

The transportability of geothermal heat is a significant limiting feature of direct use applications. Factors which influence transportability include initial and end-use temperatures, climate conditions, and whether steam or hot water is transporting the heat. Hot water can be transported much farther than steam. Depending on the direct use application, hot water can be transported about ten miles. Thus direct use facilities should be situated in close proximity to electric generation facilities.

The eastern and southeastern areas at the proposed Kilauea middle east rift GRS are presently zoned agricultural. The major portion of this proposed GRS is zoned conservation. It must be determined during subsequent permitting processes whether direct use applications of geothermal heat is an appropriate use in the agricultural and conservation areas of the proposed GRS (see section on compatibility). However, direct use activities are not legally restricted to geothermal resource subzones (Act 296 only restricts electrical uses to subzones).

If the benefits of direct use applications are to be available in several areas, then small decentralized geothermal facilities should be encouraged. Decentralized developments owned and operated by various developers may also promote competitive pricing for both electricity and process heat. With imaginative marketing, Big Island processed farm products can be sold world-wide.

Other Considerations

As described above, the Big Island's demand for electricity is expected to be fairly stable. Considering existing electric generation capacity, the demand for geothermal electricity may be somewhat limited. However, two possible long-term scenarios would significantly increase the demand for geothermal electricity: (1) a deep water electrical transmission cable connecting the islands and/or (2) an energy intensive industry on the Big Island, e.g., manganese nodule processing. Either of these scenarios could increase demand by 250 MW. However, each of these projects require a thorough analysis of many issues, including environmental and social impacts and technical and economic feasibility. These issues are beyond the scope of this report. The State Department of Planning and Economic Development has been coordinating investigations in these areas.

ENVIRONMENTAL IMPACTS FROM GEOTHERMAL DEVELOPMENT

Geothermal factors with a possible effect on the environment include air emissions, liquid effluent, noise, visual aesthetics, and physical disturbance during construction.

Air Emissions

The most significant geothermal emission is hydrogen sulfide (H_2S). Chemical analyses on unabated, undispersed, geothermal steam at the Hawaii Geothermal Project - well A (HGP-A) indicate H_2S concentrations of 900 parts per million by weight (ppmw)* (Thomas, 1983). Other potential geothermal reservoirs in Hawaii may vary. H_2S abatement systems and air dispersion will lower this concentration dramatically.

The State Department of Health (DOH) has issued proposed Ambient Air Quality Standards which will control H_2S emissions from geothermal wells and power plants (Chapters 11-59 and 11-60 of the DOH Administrative Rules). The developer must obtain from the DOH an "authority to construct" prior to geothermal well construction and a "permit to operate" prior to connecting a well to a power plant (§11-60-23.1(d)). Geothermal wells and plants would have to show compliance with the following proposed standards:

- 95% H_2S abatement at well-head; i.e. before well is connected to a distribution system emissions of H_2S shall not exceed 5 pounds per 100 pounds of H_2S in the geothermal resource (§11-60-23.1(b)).
- 98% H_2S abatement from a power plant; i.e. after well is connected to a distribution system emissions of H_2S shall not exceed 2 pounds per 100 pounds of H_2S in the geothermal resource (§11-60-23.1(c)). See also (§11-6023.2(b)).

*One ppm is approximately equivalent to one drop in 15 gallons.
One part per billion (ppb) is approximately equivalent to
1 drop in 15,000 gallons.

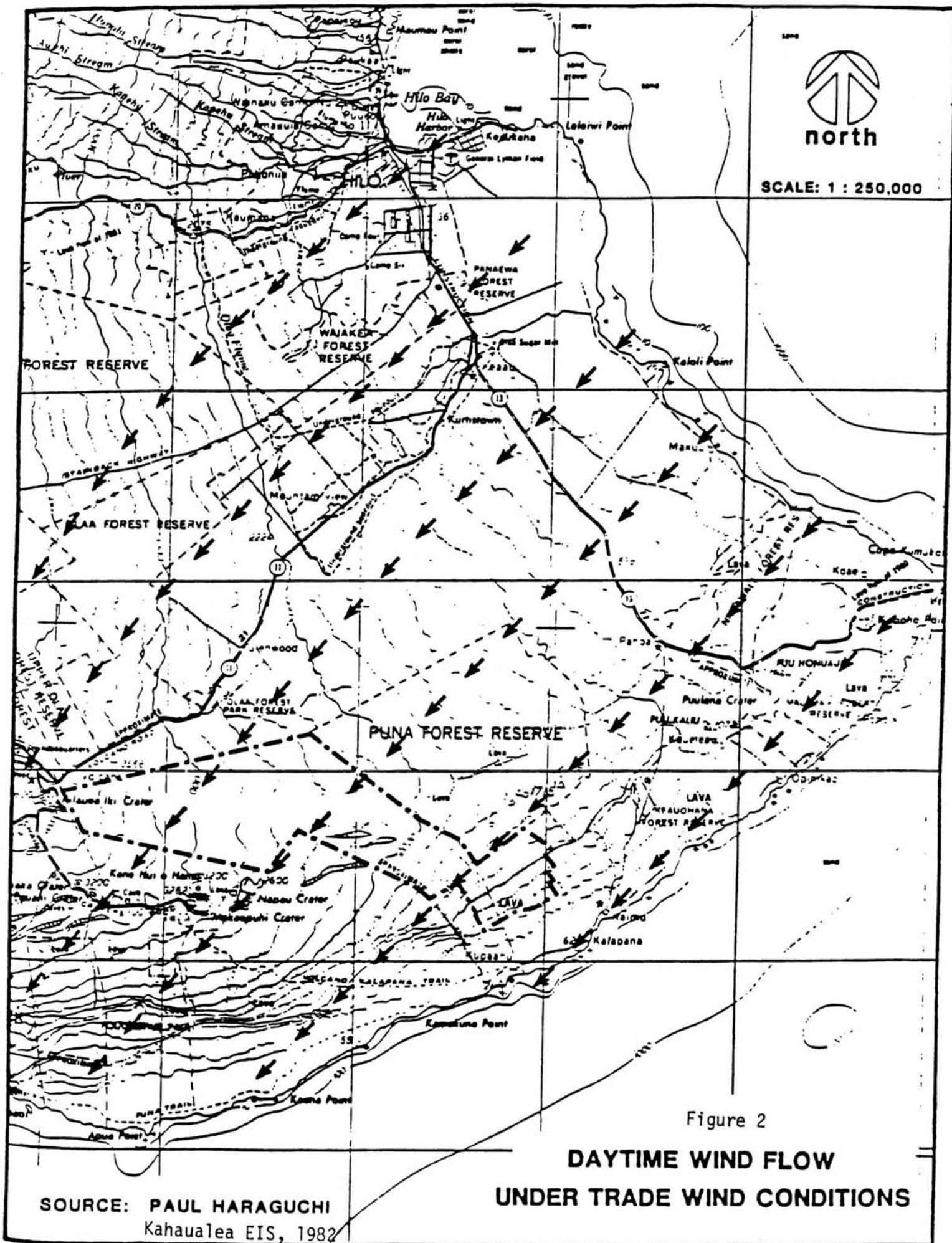
- The maximum allowable increase in H_2S in the ambient air above natural background levels during any one-hour average shall not exceed 25 ppb* considering all stationary sources. This increase may be exceeded only once per year (§11-60-23.2(c)).

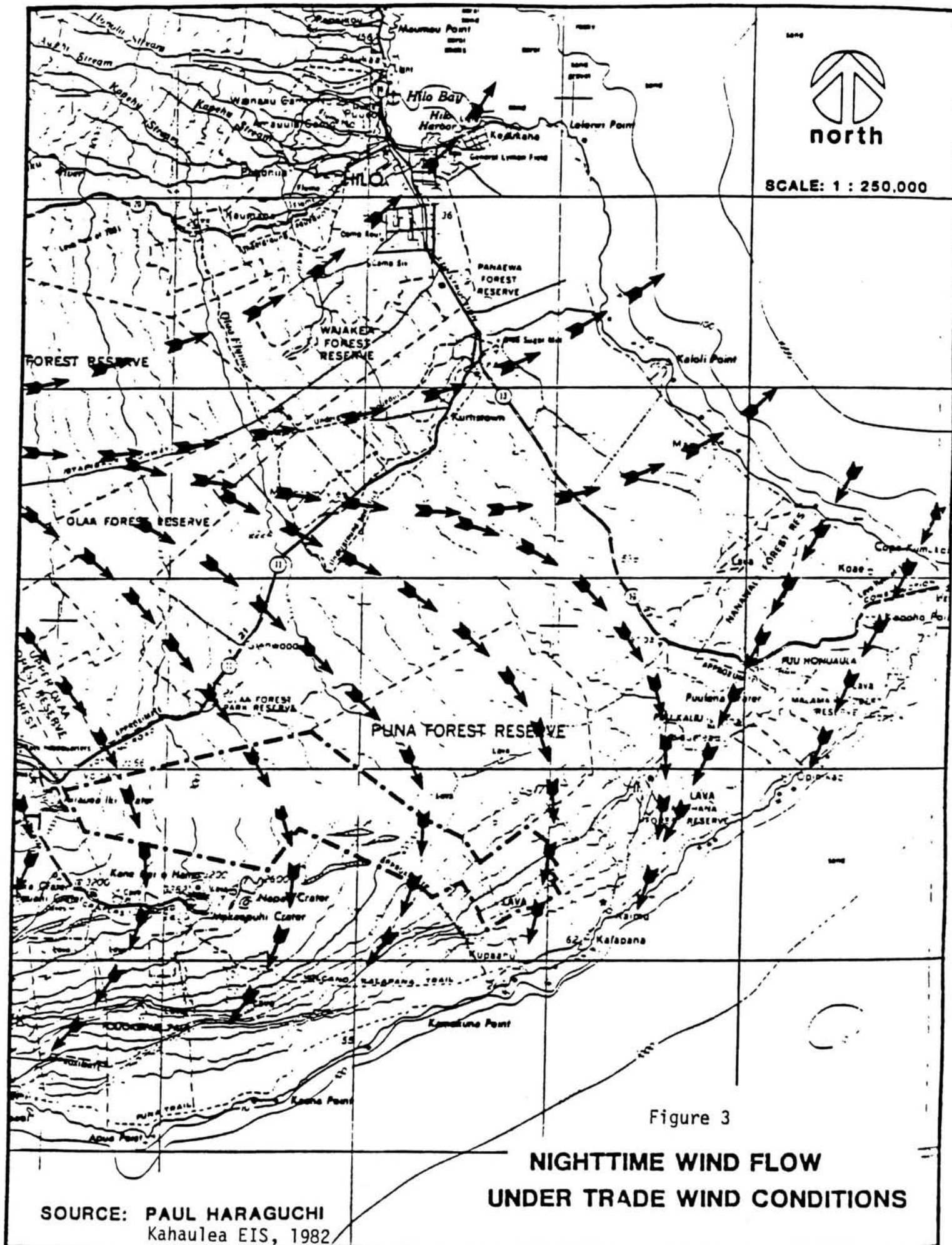
A preliminary assessment of the levels of H_2S which can be expected from geothermal developments in Hawaii has been prepared by J. Morrow (1985). He concludes that under the most unfavorable atmospheric conditions "a 25 MW plant with at least 98% H_2S removal efficiency appears capable of meeting the previously proposed state increment and ambient standard under normal and abnormal (steam stacking) operating conditions. Larger plant sizes may need higher efficiency H_2S control systems and or adequate buffer zones in order to meet the proposed increment and standard."

Daytime and nighttime wind flow patterns over the proposed Kilauea middle east rift GRS are provided in Figures 2 and 3.

The State DOH will set all standards necessary to protect the public health. Geothermal developers must demonstrate that these standards will be met both prior to construction and during operation. Technologies exist which have demonstrated abatement of H_2S emissions by approximately 99%. (For general information on geothermal wells, power plants, and abatement see DLNR Circular C-108 "Geothermal Technology" and also U.S. Environmental Protection Agency Publication "Evaluation of BACT and Air Quality Impact of Potential Geothermal Development in Hawaii.")

*The State DOH incremental standard is actually stated as 35 ug/m^3 . This can be converted to ppb (at standard pressure and 77°F) by dividing by 1.39, i.e. $35 \div 1.39 = 25 \text{ ppb}$.





Effects of Hydrogen Sulfide in Humans

The National Research Council Committee on Medical and Biological Effects of Environmental Pollutants issued a report in 1979 titled "Hydrogen Sulfide". They report that "the odor of H_2S is nothing more than an unpleasant nuisance...yet at higher concentrations it is a deadly poison...its typical 'rotten egg' odor is detectable by olfaction at very low concentrations [0.035 ug/liter or 25 ppb] in the air. Exposures to these low concentrations have little or no importance to human health. Thus, this olfactory response is a safe and useful warning signal that a hydrogen sulfide source is nearby. However at higher concentrations [280ug/liter or 200 ppm] H_2S is distinctly dangerous...(At sufficient concentrations) hydrogen sulfide is an irritant gas. Its direct action on tissues includes local inflammation of the moist membranes of the eye and respiratory tract."

The California Department of Health Service (1980) reported that "we have not become aware of any complaints of ill health due to H_2S where the 30 ppb standard has been enforced in California...there is no evidence that a more restrictive standard would achieve a perceptible improvement in the public health."

The World Health Organization (1981) reported that " H_2S in concentrations of the order of the odor threshold has not been shown to have any significant biological activity in man or animals."

Human responses to H_2S are listed in Figure 4.

In February 1984, the Hawaii DOH conducted a door-to-door health interview survey of a residential community, Leilani Estates, located near the 3 MW HGP-A geothermal power plant in the Puna District. The primary purposes of this survey were to establish the health status of Leilani Estates and to compare it to Hawaiian Beaches Estates and other areas of Hawaii. The rates of chronic respiratory conditions including bronchitis/emphysema, asthma, hayfever, sinusitis, and other respiratory system disease were found to be similar in Leilani Estates and Hawaiian Beaches Estates from January 1983 to January 1984. These conditions have been most often associated with long-term exposure to air pollutants.

Effects of hydrogen sulfide exposure at various concentrations in air

Effect	Concentration		Duration of exposure	Reference
	mg/m ³	ppm		
Man Approximate threshold for odour	0.0007—0.2	0.0005—0.13	A few seconds to less than 1 min	Yant (1930); Ryazanov (1962); Adams & Young (1968); Leonardos et al. (1969); Lindvall (1970); Thiele (1979); Winneke et al. (1979)
Threshold of eye irritation	16—32	10.5—21	6—7 h	Elkins (1939) Nessweltha (1969)
Acute conjunctivitis (gas eye)	75—150	50—100	> 1 h	Yant (1930)
Loss of sense of smell	225—300	150—200	2—15 min	Sayers et al. (1925)
Animals* Local irritation and slight systemic symptoms; possible death after several hours	750—1050	500—700	< 1 h	Haggard (1925)
Systemic symptoms; death in less than 1 h	1350	900	< 30 min	Haggard (1925)
Death	2250	1500	15—30 min	Haggard (1925)

* These observations were made in experimental animals. However, there are no better quantitative data available concerning man with respect to exposure to hydrogen sulfide at high concentrations. Source: Hydrogen Sulfide (1981), World Health Organization.

Note: The above concentrations are stated in parts per million (ppm). The Hawaii Department of Health incremental standard has been stated in parts per billion, i.e. 25 ppb or .025 ppm which is within the range of the odor threshold stated in the above table.

Figure 4

Most H₂S information pertains to its short-term effects. Information on long-term, low-level effects of H₂S is limited. The following report on H₂S levels in New Zealand considers long-term effects.

S.M. Siegel (1984), in a preliminary report for the Hawaii Natural Energy Institute, investigated the effects of H₂S at Rotorua, New Zealand. The air in Rotorua contains emissions from volcanic vents and has a 200 MW geothermal electric plant (unabated H₂S emissions) situated nearby. Within Rotorua 32 sites were sampled for H₂S. Some sites having high H₂S concentrations include: two school sites at 30-50 ppbv, two hospitals at ≥ 50 ppbv and two hotels at 50 ppbv. Hospital records from an area with a relatively high level of H₂S were compared with hospital records from an area with very low H₂S levels (no volcanic or geothermal plant emissions in latter area). Siegel found that "the incidence of diseases sampled, whether potentially related to H₂S exposure or not is not significantly different in the two Hospital Board Districts. Especially important are the absence of extra cases relating to blood-forming organs; central or sensory nerve functions; respiration; or dermatitis." He also compared infant mortality rates in three areas and found that their mortality rates were "not in any way concerned with H₂S exposure." Siegel concludes that "there is no question that Rotorua is odorous and objectively high in H₂S, often well above the California (and Hawaii) air quality standard of 30 ppbv. Rotorua and its environs have, by U.S. standards, such high levels of H₂S in residential, hospital, school, recreational and resort locations, yet reveal no evidence of health impairments."

Effects of H₂S on Plants

Thompson and Kats (1978) report pronounced stimulation of growth with alfalfa, sugar beets, and lettuce at low dosages of H₂S (30-100 ppb). At higher dosages (300-3000 ppb), H₂S fumigation caused leaf lesions, defoliation, and reduced growth in some plants. They noted that the "use of continuous, unvarying fumigation levels for exposing plant species may be unrealistic when compared to the

exposures experienced by vegetation in the field, where the vagaries of wind, convection, etc., cause varying dilution effects."

The Hawaii Natural Energy Institute (HNEI) will administer the Puna Geothermal Research Facility which will be operational by late 1985. It will accommodate geothermal research which will investigate the effects of H₂S on food crops and native Hawaiian plants.

Direct physical disturbance by geothermal construction activities should be carefully planned to minimize damage in prime environmental areas. Native forests may be susceptible to invasion by exotic species along roadways or other cleared areas. Weed control programs may be required which can minimize these impacts.

Liquid Effluent from Geothermal Development

Significant elements in geothermal brine include silica, chloride, and sodium (see Figure 5 for listing of elements in HGP-A brine). If not disposed of properly these elements have the potential to pollute potable water. Disposing of or minimizing the solids from silica deposition is a subject of concern whether the brine is discharged into a surface percolation pond or reinjected into deep rock strata. Some future projects at the Puna Geothermal Research Facility will investigate solutions to the problem of silica deposition. Aesthetic considerations may require brine disposal by reinjection. Geothermal development permits should indicate what method of brine disposal will be required.

The State DOH has established an Underground Injection Control program designed to protect the state's underground sources of drinking water (Chapter 11-23). These laws will regulate underground injections of geothermal fluids such that underground sources of drinking water are not polluted.

Groundwater monitoring and control can be required by development permits. The Board of Land and Natural Resources (BLNR) Decision and Order which allowed limited geothermal exploration at Kahaualea included the following sections: §9.2.6 requires water analyses during initial well drilling; §9.6.9 prohibits

<u>Element</u>	<u>Concentration, ppm</u>
Arsenic	0.01 - 0.001 ^b
Barium	2
Boron	2
Calcium	218
Cadmium	<1.0 ^c
Carbonate	75
Chloride	7200
Cobalt	0.014
Copper	<0.004
Gold	<0.00004
Iron	0.02
Lead	<1 ^c
Lithium	0.034
Magnesium	0.131
Manganese	0.034
Mercury	<0.001
Molybdenum	0.067
Nickel	<0.02
Niobium	<0.4
pH	7.4 ^d
Phosphorous	0.2
Platinum	<0.006
Potassium	600
Silica	800
Silver	<0.02
Sodium	3700
Strontium	2.0
Sulfate	50
Sulfide	17
Tantalum	<0.001
Thallium	<1 ^c
Tin	<0.2
Titanium	0.006
Uranium	0.16
Vanadium	0.016
Zinc	0.012

^a Liquid samples taken from cyclone separator (Thomas, 1983a).

^b Rough estimate based on preliminary analysis, Thomas, 1983b.

^c Thomas, 1982b. 'Less than' signs indicate detection limit of analyzer.

^d Before atmospheric flashing, Thomas, 1982a.

Particulate Composition of HGP-A Brine.
(Source: Dames & Moore, 1984)

Figure 5

pollution of ocean and rivers by geothermal brine; and §9.6.10 states that no substances from geothermal wells shall be allowed to flow on the ground in such a manner as to create a health hazard.

Noise Impacts

The County of Hawaii Planning Department has issued Noise Level Guidelines which have been attached to county permits controlling geothermal activities (in areas zoned urban, agricultural, or rural). These guidelines include the following:

- a. That a general noise level of 55 dBA during daytime and 45 dBA at night not be exceeded except as allowed under b. for the purposes of these guidelines, night is defined as the hours between 7:00 p.m. and 7:00 a.m.;
- b. That the allowable levels for impact noise be 10 dBA above the generally allowed noise level. However, in any event, the generally allowed noise level should not be exceeded more than 10% of the time within any 20 minute period; and
- c. That the noise level guidelines be applied at the existing residential receptors which may be impacted by the geothermal operation.

The BLNR has also similarly controlled noise associated with geothermal activities in areas zoned conservation. The BLNR Decision and Order of February 25, 1983 which allowed limited geothermal exploration on a portion of the Kahaualea land parcel in Puna, Hawaii, included the following noise level restrictions:

§9.3.5 - A general noise level of 55 dba during daytime and 45 dba at night shall not be exceeded except as allowed for impact noise. For the purposes of these guidelines, night is defined as the hours between 7:00 p.m. and 7:00 a.m. These general noise levels may be exceeded by a maximum of 10 dba for impact noise; however, in any event, the generally allowed noise level shall not be exceeded more than 10 percent of the time within any

20-minute period with the exception of venting operation in accordance with Chapter 183 of Title 13 of the Board's Administrative Rules and this order.

The above decibel limits are related to everyday sounds noted in Figure 6.

The State DOH has issued noise regulations for Oahu. Presently the DOH does not control noise on a state-wide level.

Aesthetic Aspects

Geothermal developments may minimize their visibility by considering nearby view corridors during site selection. Sites close to forest areas will minimize development visibility; however, this advantage must be balanced with possible damage that may occur to the forest. Aesthetics may also be improved by tasteful development design, landscaping, and painting of structures.

Visibility of steam emissions from cooling towers will vary with output and atmospheric conditions; however, use of drift eliminators can reduce the size of the vapor plume. Silica deposition from surface disposal of geothermal brine can also create an aesthetic problem. Brine could be reinjected into deep rock strata. As an alternative, research may provide an aesthetic and environmentally acceptable brine treatment process.

Flora and Fauna in the Proposed Kilauea Middle East Rift GRS

A detailed vegetation survey of the Puna, Hawaii area was conducted by J.D. Jacobi (1983). The surveyed areas were mapped into approximately eight vegetation categories. (See "Vegetation Map of the Puna Study Area-Wet Habitat", U.S. Fish and Wildlife Service, Mauna Loa Field Station, Hawaii.)

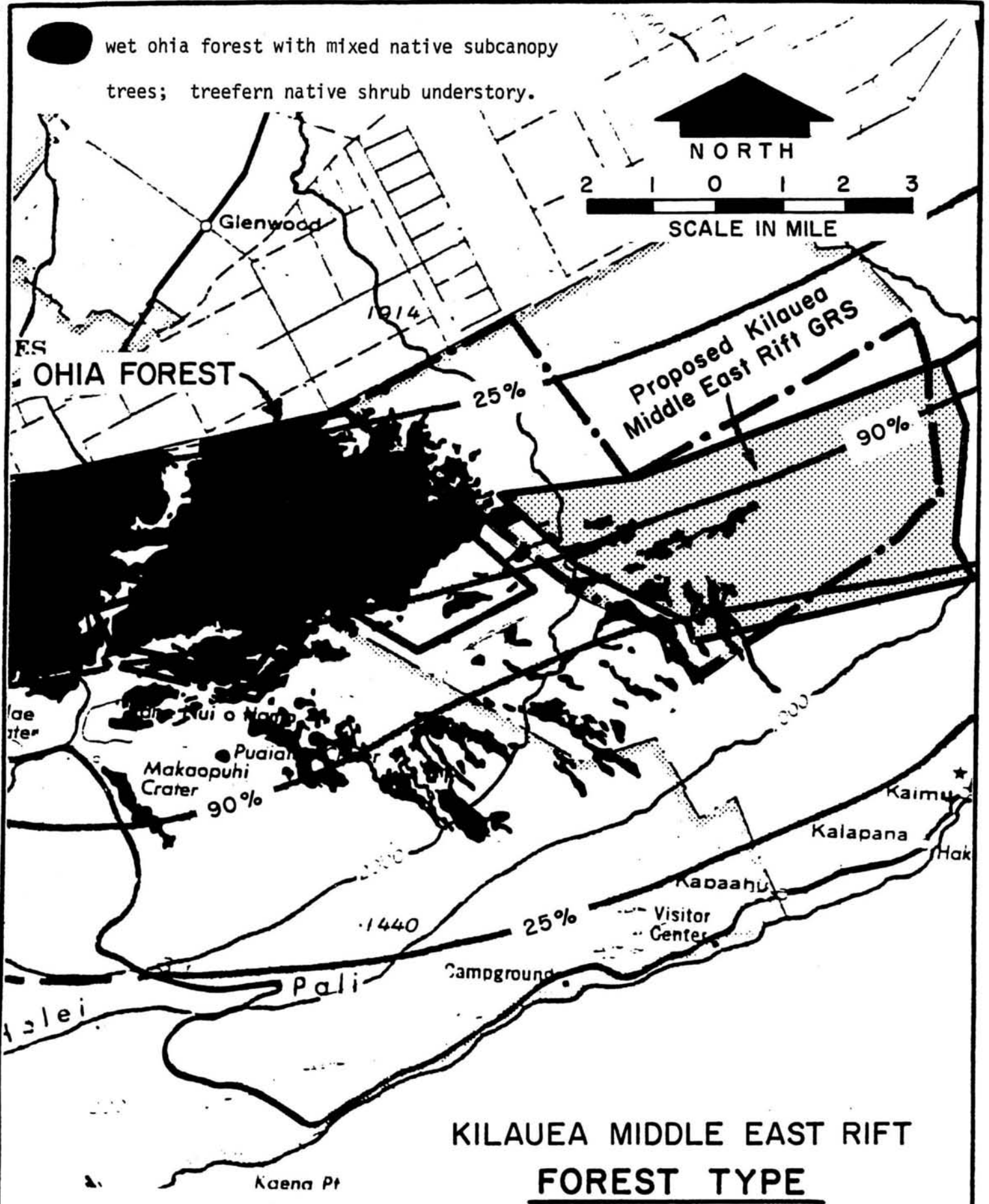
Figure 7 shows the highest quality native vegetation in the Kilauea middle east rift zone area. It is classified as "wet ohia forest with mixed native subcanopy trees; treefern native shrub understory." The greatest quantity of this prime native vegetation class is uprift

Sound Levels and Human Response

<u>Common Sounds</u>	<u>Noise Level (dB)</u>	<u>Effect</u>
Air raid siren	140	Painfully loud
Jet takeoff (200 ft)	120	Requires maximum vocal effort
Auto horn (3 ft)		
Discotheque		
Alarm clock (2 ft)	80	Annoying
Hair dryer		
Freeway traffic	70	Telephone use difficult
Man's voice (3 ft)		
Air conditioning (20 ft)	60	Intrusive
Light auto traffic (100 ft)	50	Quiet
Living room	40	
Bedroom		
Library	30	Very quiet
Soft whisper (30 ft)		

This decibel (dB) table compares some common sounds and shows how they rank in potential harm to hearing. Note that 70 dB is the point at which noise begins to harm hearing. To the ear, each 10 dB increase seems twice as loud. (Source: U.S. Environmental Protection Agency)

Figure 6



Source: Vegetation Map of the Puna Study Area-
Wet Habitat, Jacobi 1983.

KILAUEA MIDDLE EAST RIFT FOREST TYPE

Island of Hawaii

Figure 7

and outside of the proposed Kilauea middle east GRS; however, some areas exist in the western part of the proposed GRS. Aside from its intrinsic value, this vegetation can provide a source of native seed for bare lava areas in the region. Other vegetation in the southwestern part of the proposed GRS is classified as "closed canopy, wet ohia forest with mixed native subcanopy trees; treefern-native shrub understory with some introduced shrubs and ferns." There are also small sections of ohia-kukui forest in the southwestern section. (The kukui trees may have been planted by the early Hawaiians.)

The northern part of the proposed GRS includes a large section of vegetation classified as "open canopy, wet ohia forest with mixed native subcanopy trees; treefern native shrub understory with some introduced shrubs and ferns".



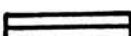


The southeastern section of the proposed GRS includes a large section of vegetation classified as "wet pioneer ohia community (trees less than 10m tall)."

A significant part of the proposed GRS is comprised of mostly bare recent lava (1963 to 1985 flows) (see geologic hazards section).

Endangered plants in the area include the fern *Adiantum* species, which has been sighted mostly outside of the proposed GRS to the west and north.

This area has also been surveyed recently by the University of Hawaii Botany Department for the State Department of Planning and Economic Development. Their forthcoming report, titled Puna Geothermal Area Biotic Assessment, will include recent effects from volcanic activity and wild animals on existing vegetation.

Endangered birds in the Kilauea middle east rift include the O'u, the I'o (Hawaiian Hawk), and the Nene (Hawaiian goose). The distributional area of these birds for the island of Hawaii is depicted in Figure 8. Distributional areas indicate those areas where these birds have been sighted. Possible reasons for the declining population of Hawaii's endangered birds include avian disease, animal competition, collecting and hunting, elimination or degradation of habitat, and predation.

-  I'o (Hawaiian Hawk) distribution
-  O'u distribution
-  Nene (Hawaiian Goose) distribution
-  Proposed geothermal resource subzone
-  Existing geothermal resource subzone

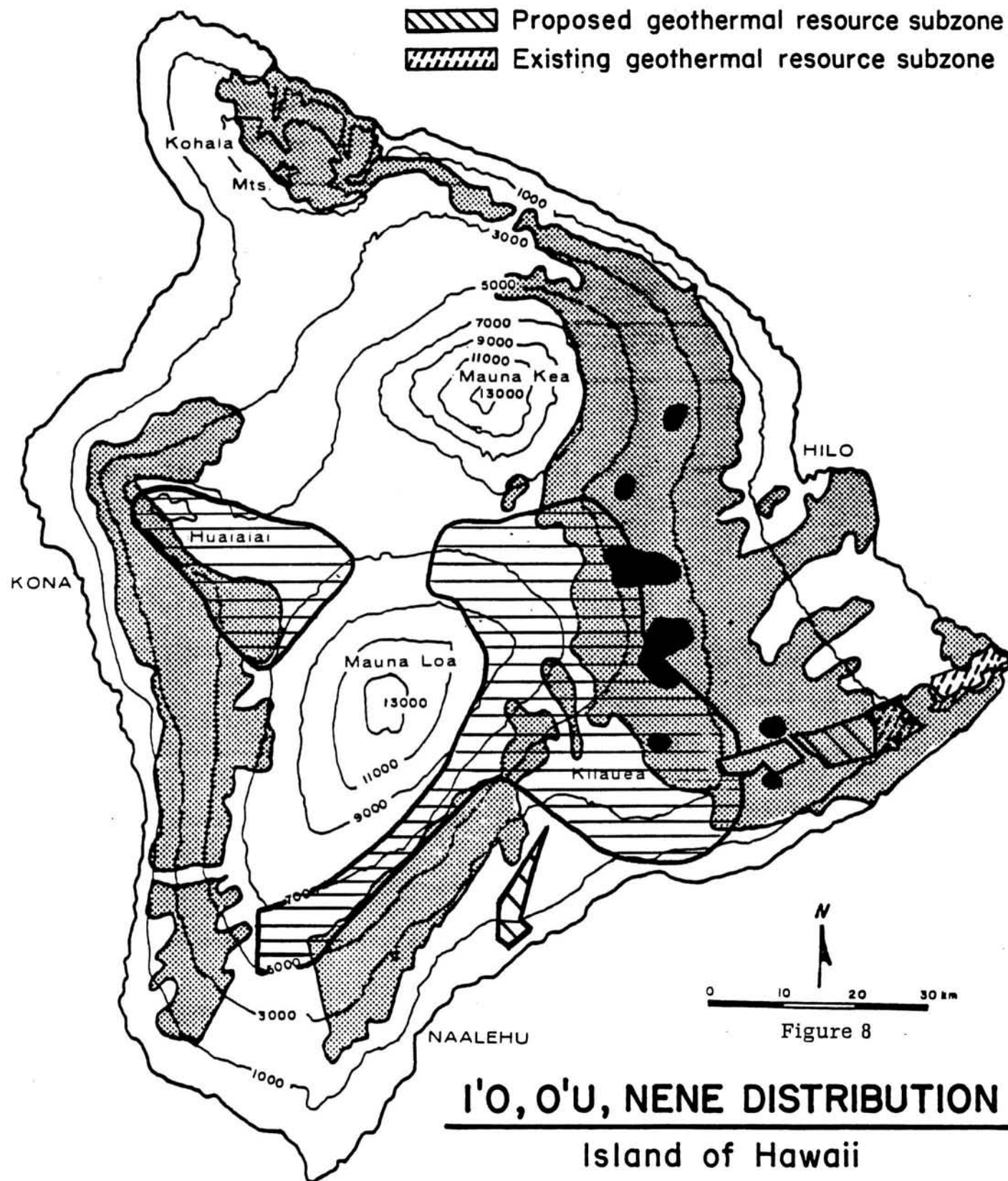


Figure 8

I'O, O'U, NENE DISTRIBUTION

Island of Hawaii

Source: U.S. Fish & Wildlife Service

The Hawaii Forest Bird Recovery Plan describes the O'u as a rather large bird (about 6"). The males have bright yellow heads clearly separated from dark green backs and light green underparts. The female lacks the yellow head. Their straw-colored parrot-like bill is distinctive. Less than 40 O'u were recorded during the 13,500 count periods conducted during the Hawaii Forest Bird Survey. The O'u population on the Big Island has been estimated at about 500 birds. O'u sightings have been reported west and north of the proposed Kilauea middle east rift GRS (Figure 8). The authors of the Hawaii Forest Bird Recovery Plan have recommended an essential habitat for the O'u (Figure 9) which they believe to be necessary for the O'u to be restored to non-endangered status.

The endangered I'o or Hawaiian hawk is a roaming bird which has been sighted throughout the Puna area (Figure 8). The I'o population is currently estimated to be 1400-2500 birds, all on the Big Island. Light and dark color variations exist for the I'o. The light phase I'o has a generally dark brown head and back with a white chest and belly. The dark phase I'o is generally dark brown all over.

The Hawaii Division of Fish and Game has conducted a project for the last 30 years to propagate Nene for release into the wild. Once plentiful, the endangered Nene population had dwindled to an estimated 30 birds in 1952. Through controlled propagation efforts their population on the island of Hawaii had increased to 300 birds in 1980. Figure 8 depicts their primary range which is approximately 10 km to the west of the proposed Kilauea middle east rift GRS.

GEOLOGIC HAZARDS

An analysis of Hawaiian geologic hazards and their possible effects on geothermal developments has been provided in Circular C-107, "Geologic Impact Analysis of Potential Geothermal Resource Areas", published by the Department of Land and Natural Resources,

Division of Water and Land Development. The report also describes several mitigation measures which may reduce the risk from geologic hazards.

The following paragraphs supplement Circular C-107 providing a description of the geologic activity which has occurred in or near the Kilauea middle east rift zone.

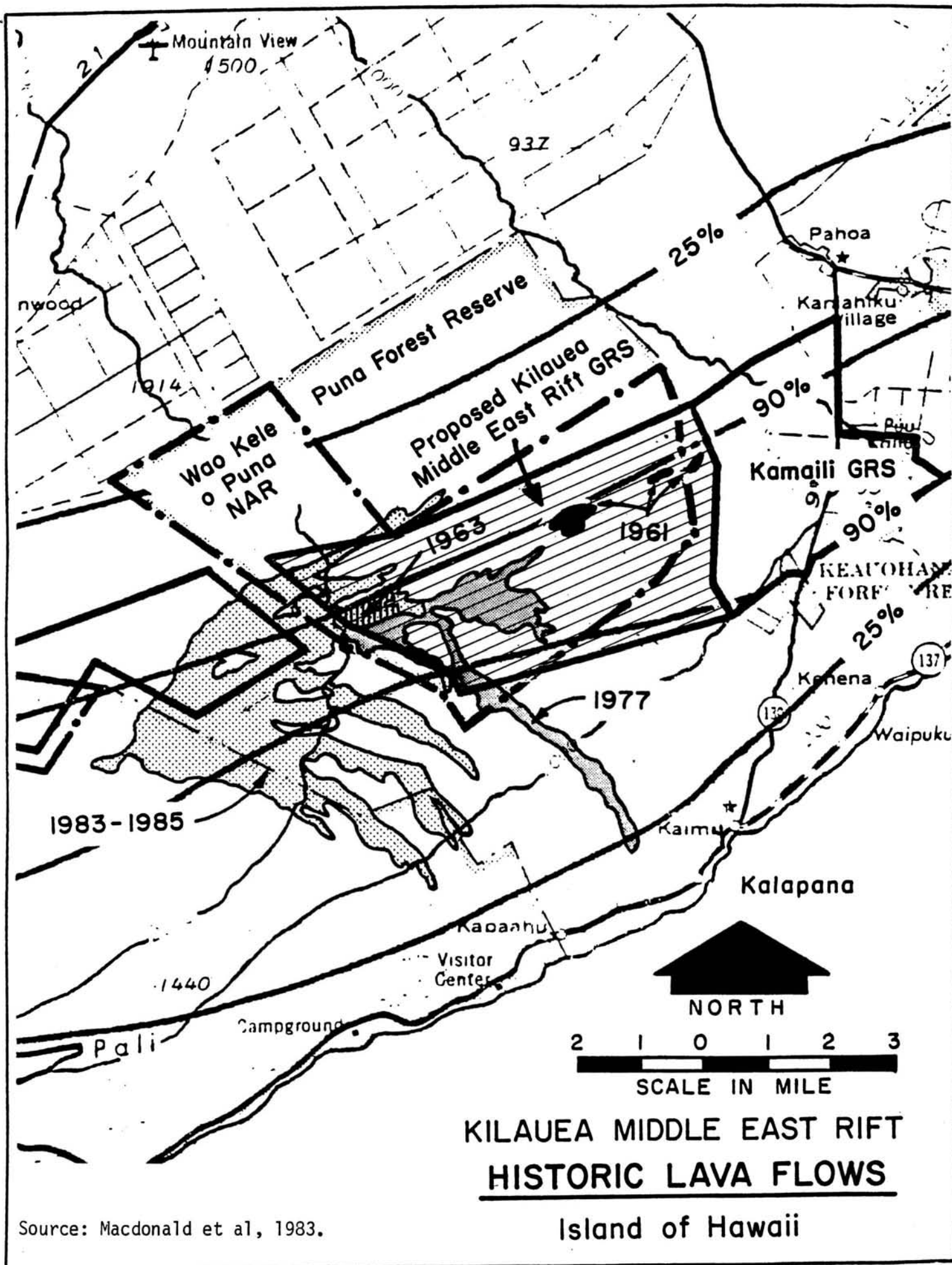
Lava Flows

Kilauea is one of the world's most active volcanoes. Although eruptions have occurred more frequently in the upper rift zone, substantial volcanic risk is present along the entire Kilauea east rift zone. Historic eruptions which have flowed at least partially into the proposed Kilauea middle east rift geothermal resource subzone (GRS) are listed in the table below and depicted in Figure 10.

Date of Outbreak	Duration	Area (km ²)	Volume (m ³)
1750 (approximate date)		4.1	14,200,000
1961, September 22	3 days	.8	2,200,000
*1963, October 5	1 day	3.4	6,600,000
1977, September 13	18 days	7.8	32,900,000
*1983, January to present	2 years+	37+	335,000,000+

*Eruption originated uprift and flowed into the proposed Kilauea middle east rift GRS.

The elevation of mildly sloping ridges north of the middle east rift zone axis may offer some protection from lava hazards. Heiheiiahulu Crater in the southeast portion of the proposed GRS may be considered as an elevated geothermal site. Other mitigation techniques outlined in Circular C-107 may be appropriate. Steep slopes of up to 80% within the southern part of the proposed Kilauea middle east rift GRS can provide a likely path for and increase the speed of lava flows originating upslope.



Source: Macdonald et al, 1983.

**KILAUEA MIDDLE EAST RIFT
HISTORIC LAVA FLOWS**
Island of Hawaii

Within the past 24 years four eruptions have covered parts of this proposed GRS. These flows have been concentrated in the western part of the proposed GRS. The 1961 flow covered 1% of the proposed GRS, the 1963 flow 2%, the 1977 flow 10% and the present Puu O'o flows 9%. The total percentage of land in the proposed GRS covered by these recent flows is about 22%. This figure can be extrapolated over the expected 30-year useful life of geothermal plant equipment. Based on these recent eruptions we might expect about 27% of the land area in the proposed GRS to be covered by lava in the next 30 years. Puu O'o is presently providing the least resistive path to the surface for intrusive magma in the Kilauea east rift zone. It is unlikely that eruptions will occur downrift while the Puu O'o eruptions continue. However, it is not possible to accurately predict the precise time and place of future activity.

Decentralized facilities, strategic siting, and prudently constructed lava diversion platforms and barriers can be expected to mitigate the hazard risk from future flows. However, nothing can eliminate the substantial hazard from lava flows.

Pyroclastic fallout

Weight and depth of pyroclastic fallout is greatest around an eruptive vent. However, fallout can be appreciable 500 to 1000 m downwind of a vent. In 1959, a light pumice blanket extended 4000 m southwest from Kilauea Iki vent. In February 1985, high fountaining during the 30th phase of the Puu O'o eruption and strong NE Kona winds resulted in an appreciable amount of Pele's hair falling out over Hilo.

Protecting structures or machinery against damage by pyroclastic fallout may be achieved by enclosing those parts vulnerable to abrasion or contamination.

Ground Cracks

Volcanic cracking is concentrated along the rift zone axis. A significant number of volcanic cracks are situated within the proposed

Kilauea middle east rift GRS. Many cracks may be associated with a single volcanic event, as evidenced by the cracks formed during the 1961 eruption (Figure 11). Contingency planning should include the best available methods for sealing a well bore should a crack intercept a producing well.

Earthquakes

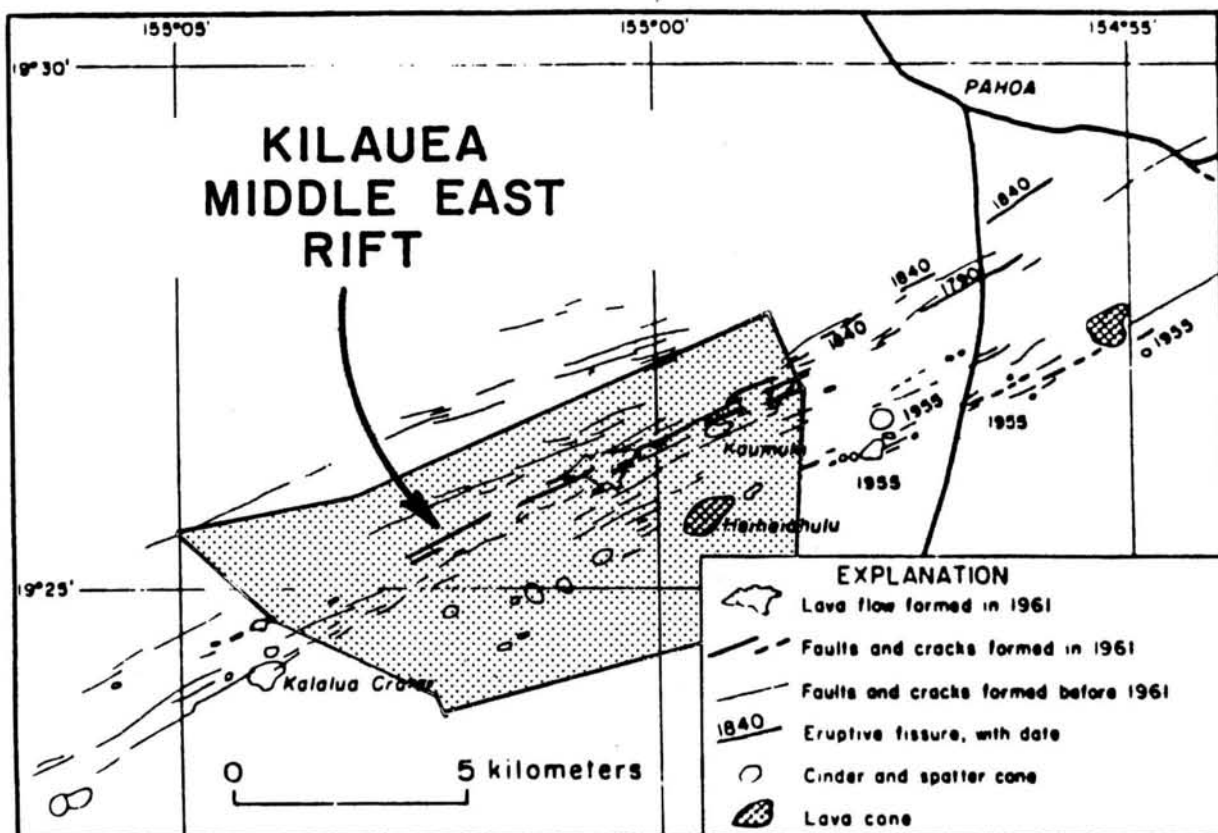
Most earthquakes in Hawaii are volcanic, which are small in magnitude and cause little direct damage. Larger tectonic earthquakes tend to be situated in the saddle area between the calderas of Kilauea and Mauna Loa, and also in the Koa'e and Hilina fault systems--south of Kilauea's caldera. Recent earthquakes above magnitude 6 have occurred in the saddle area, e.g. the Kaoiki earthquake in November, 1983 (magnitude 6.7). The largest recent earthquake (magnitude 7.2) occurred in 1975 about 5 km southwest of Kalapana.

Subsidence

Subsidence may occur within the rift zone. As a result of volcanic activity, grabens may result with the subsidence of rock between parallel cracks, e.g. 1960 Kapoho graben. Subsidence may also occur with tectonic earthquakes, collapsing lava tubes, and pit craters.

Tsunamis

Tsunami hazard is probably localized to a zone of land at most 2 km wide around the coast, and at elevations below about 75 feet. This will not be a hazard to developments in the proposed Kilauea middle east rift GRS as elevations are generally above 1400 feet.



Map of the Kilauea middle east rift zone showing area faults and cracks. The proposed Kilauea middle east rift geothermal resource subzone is superimposed. Source: Modified after Richter, 1964; in Macdonald, 1983.

Figure 11

LAND USE COMPATIBILITY

The great majority of the land within the proposed Kilauea middle east rift GRS is zoned Conservation-Protective. This conservation area is also presently designated as the Wao Kele 'O Puna Natural Area Reserve and the Puna Forest Reserve. The extreme eastern and southeastern areas of this proposed GRS is zoned agricultural.

Act 296 SLH 1983, specifically states that "geothermal resource subzones may be designated within each of the land use districts under section 205-2."

Under the provisions of Chapter 205-2 of the Hawaii Revised Statutes, Districting and Classification of Lands, there are four major land use districts in which all lands in the State are be placed: (1) urban, (2) rural, (3) agricultural, and (4) conservation.

Urban districts include activities or uses as provided by ordinances or regulations of the county within which the urban district is situated.

Rural districts include activities or uses as characterized by low density residential lots of not more than one dwelling house per one-half acre in areas where 'city-like' concentration of people, structures, streets, and urban level of services are absent, and where small farms are intermixed with the low density residential lots. These districts may include contiguous areas which are not suited to low density residential lots or small farms by reason of topography, soils, and other related characteristics.

Agricultural districts include activities or uses as characterized by the cultivation of crops, orchards, forage, and forestry; farming activities or uses related to animal husbandry, and game and fish propagation; services and uses accessory to the above activities including but not limited to living quarters or dwellings, mills, storage facilities, processing facilities, and roadside stands for the sale of products grown on the premises; agricultural parks and open area recreational facilities.

Conservation districts include areas necessary for protecting watersheds and water sources; preserving scenic and historic areas; providing park lands, wilderness, and beach; conserving endemic plants, fish, and wildlife; preventing floods and soil erosion; forestry; open space areas whose existing openness, natural condition, or present state of use, if retained, would enhance the present or potential value of abutting or surrounding communities, or would maintain or enhance the conservation of natural or scenic resources; areas of value for recreational purposes; and other related activities; and other permitted uses not detrimental to a multiple use conservation concept.

Permitted uses in the Conservation-Protective subzone are:

- Research, recreational and educational uses which require no physical facilities;
- Establishment and operation of marine, plant and wildlife, sanctuaries and refuges, wilderness and scenic areas, including habitat improvement;
- Restoration or operation of significant historic and archaeological sites listed on the National or State Register;
- Maintenance and protection of desired vegetation, including removal of dead, deteriorated and noxious plants;
- Programs for control of animal, plant and marine population, to include fishing and hunting;
- Monitoring, observing and measuring natural resources;
- Occasional use; and
- Any other government facilities not enumerated herein where the public benefit outweighs any impact on the Conservation District.

The DLNR's administrative rules define conservation to mean:

"A practice, by both government and private landowners, of protecting and preserving, by judicious development and utilization, the natural and scenic resources attendant to land...to ensure optimum long-term benefits for the inhabitants of the State." (DLNR Rule 13-2-1)

These rules also state that conservation land "use shall be compatible with the locality and surrounding areas, and appropriate to

the physical conditions and capabilities of the specific parcel or parcels of land." (DLNR 13-2-21 (a) (1)).

In granting a conservation district use permit (CDUA No. HA 3/2/82-1463) for geothermal exploration, the Board of Land and Natural Resources (BLNR) stated that "the State recognizes that conservation lands vary in their use and importance in accordance with a wide variety of criteria. Both the federal government and the State of Hawaii recognize that conservation lands involve multiple uses which range from absolute preservation to regulated uses...The range of activity permitted depends upon the ecological importance of the resource in the overall environment and the relative need for human activity within a restricted context." This balancing test may also be applied by the BLNR to conservation lands contained within the proposed Kilauea middle east rift GRS when subzoning is determined.

The counties control land use within agricultural districts. The County of Hawaii has already permitted the drilling of several geothermal wells on land zoned agricultural near the HGP-A geothermal facility. With regard to agricultural zoned land within the proposed Kilauea middle east rift GRS, the County will assess the propriety of geothermal development before granting their geothermal permits.

CONCLUSION AND RECOMMENDATION

The Department of Land and Natural Resources pursuant to a under the directive by the Board of Land and Natural Resources has conducted an assessment of the Kilauea middle east rift zone in and adjacent to the Puna Forest and Natural Area Reserve.

This land area located between the western boundary of the Kamaili geothermal resource subzone and the eastern boundary of Kahaualea was examined for resource potential and evaluations were made on geologic hazards, social, economic, and environmental impacts and compatibility of geothermal development. The potential geothermal

resource area was evaluated on the basis of potential and real impacts which may occur within the identified area and consideration of statutory state energy objectives and policies.

The potential geothermal resource area was assessed to have a greater than 90% probability of locating a high temperature resource and potential impacts were identified and considerations given to mitigation measures and other requirements that may be imposed on a site-specific, case-by-case basis during subsequent State and County permitting.

Geologic hazards are substantial throughout the entire Kilauea east rift zone. Decentralization of facilities, strategic siting, and lava diversion platforms and barriers may mitigate damage from future lava flows. Development permits should require that all potential economic losses are to be assumed by developers.

The State Department of Health has proposed air quality standards and promulgated underground injection control regulations which will control geothermal emissions and effluent injections. Development permits should either prohibit or control surface water disposals. Geothermal noise levels have been regulated in exploration permits and such noise regulation is expected to continue throughout the development process.

Assuming the exchange of State and Campbell Estate lands is feasible and that Kahaualea is redesignated as a Natural Area Reserve, the proposed Kilauea middle east rift GRS will provide a 2000-foot buffer between the GRS and Kahaualea to mitigate any possible effects on the substantial prime native forest and wildlife at Kahaualea. Those pockets of prime native forest which are contained within the proposed GRS should be protected throughout the permitting process by requiring that development activities avoid these sensitive areas.

The State has established an objective of energy self-sufficiency. Geothermal energy is viewed as a key to attaining this objective. Conservation is also an area of high priority. The Division of Water and Land Development believes that both goals of geothermal development and environmental protection can be attained by permitting

controlled development within the proposed Kilauea middle east rift GRS. This assessment has resulted in the identification of approximately 11,800 acres of the Kilauea middle east rift zone as a potential geothermal resource area and recommends that it be considered for designation as a geothermal resource subzone by the Board of Land and Natural Resources under authority of Act 296, SLH 1983 and Act 151, SLH 1984.

APPENDIX A

Decision and Order of the
Board of Land and Natural Resources

BOARD OF LAND AND NATURAL RESOURCES

STATE OF HAWAII

In the Matter of the)	G.S. No. 8/27/84-1
Designation of the Kilauea)	
Upper East Rift, Island of)	
Hawaii, as a Geothermal)	
Resource Subzone)	
<hr/>		

Decision and Order on the Proposed Geothermal
Resource Subzone at Kahauale'a, Hawaii

Decision and Order of the Board of Land and
Natural Resources on the Proposed Geothermal
Resource Subzone at Kahauale'a, Hawaii

Pursuant to Act 296, SLH 1983, Act 151, SLH 1984 and Title 13, Chapter 184 of the administrative rules of the Department of Land and Natural Resources, the Board of Land and Natural Resources has been assessing potential geothermal resource areas throughout the State. Under Act 151, SLH 1984, two areas in lower Puna, Hawaii, with existing wells were grandfathered as geothermal resource subzones. On November 16, 1984, this Board designated two additional subzone areas in lower Puna on the Island of Hawaii and one on the southwest rift of Haleakala, Maui.

Today the Board is acting upon a proposal to designate a portion of land at Kahauale'a, Hawaii. In consideration of the widespread interest which this proposal generated, the Board in its discretion conducted a contested case hearing from December 12-20, 1984 in Hilo, Hawaii. Parties to those hearings submitted their proposed findings of fact and conclusions of law to the Board this past Monday, December 24, 1984.

Under Act 151, SLH 1984, the Board must make a determination by December 31, 1984 regarding the designation of all or any portion of the land which the Board approved in its Conservation District Use Permit of February 25, 1984. That decision allowed Campbell Estate to conduct limited exploration on approximately 800 acres of land in Kahauale'a. The Board has reviewed and considered the proposed findings of fact and conclusions of law submitted by the parties. In view of the statutory deadline and the brief time available to the Board since it received the proposed findings, the decision today will be rendered orally. A full written decision and order will follow at a later date.

- I. The Board of Land and Natural Resources approves the designation of the area described in the Board's Decision and Order of February 25, 1983 containing approximately 800 acres of surface area as a geothermal resource subzone upon the occurrence of the following events and upon the following conditions:
 1. The cessation of volcanic activity in, around, and near the area permitted by the Board's February 25, 1983 Decision and Order. The determination that eruptive activity constituting a geologic hazard has ceased shall be made by the Board upon evidence and testimony from professional geologists from the Hawaii Volcanoes Observatory and the U. S. Geological Survey. Other professional geologists with special experience in this particular geographic area may be heard at the Board's discretion.
 2. No new activity associated with the permitted area shall be considered until after the determination is made that geologically hazardous and eruptive activity in, near, and around the permitted area has ceased as provided for above.
- II. The State of Hawaii formally requests the Estate of James Campbell to investigate and consider a land exchange involving State owned land in Kilauea middle east rift zone and Campbell Estate's lands at Kahauale'a (excluding Tract 22).

If the State of Hawaii and Campbell Estate should later consummate a land exchange involving lands at Kahauale'a for State or other lands upon which geothermal activities may take place, then the geothermal subzone designation in this Decision and Order shall cease to exist and shall have no force or effect in law, notwithstanding any further requirement for a contested case hearing in HRS 205-5.2(3) or any other provision of law to the contrary.

- III. The Board of Land and Natural Resources on its own motion hereby directs the Division of Water and Land Development (DOWALD) of the Department of Land and Natural Resources (DLNR) to immediately undertake and conduct an assessment of the Kilauea middle east rift zone in and adjacent to the Natural Area Reserve beginning on the western boundary of the Kamaili geothermal subzone as a potential geothermal resource subzone. Although this area had not previously been evaluated due to its classification as a Natural Area Reserve, the Board now believes that the area should be reviewed.
- IV. If a) the assessment of the Kilauea middle east rift zone does not result in a designation as a geothermal resource subzone in this area; or b) a land exchange between the State of Hawaii and the Estate of James Campbell is not consummated then the remainder of the 5300 acres proposed by DOWALD as a geothermal resource subzone in Kahauale'a heretofore not designated by this Decision and Order shall be and is hereby ordered to be so designated as a geothermal resource subzone.
- V. If the land exchange described above is consummated, the Board of Land and Natural Resources strongly urges the federal government and the National Park Service to immediately seek to acquire Tract 22 (as described on its Master Plan), which the State will not itself seek.
- VI. If the exchange described above does occur, the entire 5300 acres within the proposed subzone (exclusive of Tract 22) shall be included within the lands acquired by the State of Hawaii from Campbell Estate and shall be eliminated from the proposed subzone.

Honolulu, Hawaii December 28, 1984.

IT IS SO ORDERED.

By the Board of Land and Natural Resources


SUSUMU ONO, Chairperson
Board of Land and Natural Resources


MOSES KEALOHA


ROLAND HIGASHI


THOMAS YAGI

Decision and Order on the Proposed Geothermal
Resource Subzone at Kahauale'a, Hawaii.

CERTIFICATE OF SERVICE

It is hereby certified that a copy of Decision and Order on the Proposed Geothermal Resource Subzone at Kahauale'a, Hawaii was mailed, postage prepaid, to the following persons on January 3, 1985:

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and same was hand-delivered to the following on December 28, 1984

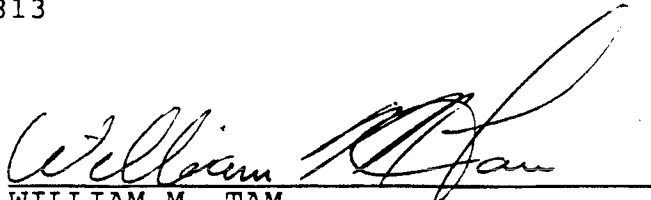
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APPENDIX B

References

ASSESSMENT OF GEOTHERMAL RESOURCE

Lew, A.A., May 1981, Land Use and Geothermal Energy Development In Lower Puna, Hawaii, Department of Research and Development, County of Hawaii.

State of Hawaii, Department of Land and Natural Resources, September 1983, Plan of Study for Designating Geothermal Resources Subzones, Circular C-97.

_____, _____, January 1984, Assessment of Available Information Relating to Geothermal RESources in Hawaii, Circular C-98.

_____, _____, March 1984, Public Participation and Information Program for Designating Geothermal Resource Subzones, Circular C-99.

_____, _____, March 1984, Geothermal Resource Developments, Circular C-100.

_____, _____, June 1981, Rules on Leasing and Drilling of Geothermal Resources, Chapter 183 of Title 13, Administrative Rules.

_____, _____, July 1984, Statewide Geothermal Resource Assessment, Circular C-103.

_____, _____, August 1984, Geothermal Technology, Circular C-108.

_____, Board of Land and Natural Resources, February 1983, CDUA No. HA 3/2/82-1463, Findings of Fact, Conclusions of Law, Decision and Order, Honolulu, Hawaii.

Thomas, D.M., 1985, Hawaii Institute of Geophysics, University of Hawaii, personal communication.

SOCIAL IMPACTS

Ellis, W., 1979, Journal of William Ellis, Rutland, Vt.

Lew, A.A., May 1981, Land Use and Geothermal Energy Development In Lower Puna, Hawaii, Department of Research and Development, County of Hawaii.

State of Hawaii, Department of Land and Natural Resources, September 1983, Plan of Study for Designating Geothermal Resources Subzones, Circular C-97.

_____, _____, March 1984, Public Participation and Information Program for Designating Geothermal Resource Subzones, Circular C-99.

_____, _____, March 1984, Geothermal Resource Developments, Circular C-100.

_____, _____, July 1984, Social Impact Analysis, Circular C-104.

_____, _____, July 1984, Economic Impact Analysis, Circular C-105.

_____, _____, August 1984, Environmental Impact Analysis, Circular C-106.

_____, _____, August 1984, Geothermal Technology, Circular C-108.

_____, Board of Land and Natural Resources, February 1983, CDUA No. HA 3/2/82-1463, Findings of Fact, Conclusions of Law, Decision and Order, Honolulu, Hawaii.

Thomas, D.M., 1985, Hawaii Institute of Geophysics, University of Hawaii, personal communication.

POTENTIAL ECONOMIC BENEFITS

Armstead, H.C., 1978, Geothermal Energy. Bristol, England, Halsted Press.

Hawaiian Electric Light Company, May 23, 1984, Forecast of Sales, Peak and Sales Load Factor.

_____, July 1983, Generating Capabilities.

State of Hawaii, Department of Land and Natural Resources, Division of Water and Land Development, July 1984, Economic Impact Analysis of Geothermal Resource Areas. Circular C-105.

Whitten, H., October 26, 1983, State Continues to Push for Petroleum Reserves. Honolulu Star Bulletin.

ENVIRONMENTAL IMPACTS

California Department of Health Services, 1981, Health Effects of Hydrogen Sulfide. Berkeley, California.

County of Hawaii, Planning Department, May 1981, Geothermal Noise Guidelines.

Dames & Moore, 1984, Report Evaluation of BACT and Air Quality Impact of Potential Geothermal Development in Hawaii. Honolulu, EPA contract #68-02-3508.

Jacobi, J.D., 1983, Mapping of Natural Vegetation of the Hawaiian Islands, U.S. Fish and Wildlife Service, Hawaii Volcanoes National Park.

Morrow, J., 1985, Geothermal Subzone Hydrogen Sulfide Impact Assessment (preliminary draft report). Honolulu.

Revised Environmental Impact Statement for the Kahaualea Geothermal Project, June 1982, a True/Mid-Pacific Geothermal Venture in Coordination with Campbell Estate.

Siegel, S.M. and Siegel, B.Z., 1984, Geothermal Hydrogen Sulfide and Health in Rotorua, New Zealand, prepared for Hawaii Natural Energy Institute, Honolulu.

State of Hawaii, Department of Health, Proposed Air Quality Standards, Chapters 11-59 and 11-60, Draft 3/22/84.

_____, _____, A Study of the Health Status of a Population Exposed to Low Levels of Hydrogen Sulfide (and Other Geothermal Effluents) in Puna, Hawaii.

_____, _____, Underground Injection Control Regulations, Chapter 11-23.

State of Hawaii, Department of Land and Natural Resources, 1984, Geothermal Technology, Circular C-108.

_____, Decision and Order, CDUA of the Estate of James Campbell #HA 3/2/82-1463, Feb. 1983.

Thomas, D.M., 1983, Recovery of Byproducts from Geothermal Development in Hawaii. Hawaii DPED contract #12892.

United States Fish and Wildlife Service, July 1982, Hawaii Forest Bird Recovery Plan.

_____, May 1984, Hawaiian Hawk Recovery Plan.

_____, February 1983, Nene (Hawaiian Goose) Recovery Plan.

World Health Organization, 1981, Hydrogen Sulfide. Geneva.

GEOLOGIC HAZARDS

Macdonald, G.A. et al, 1983, Volcanoes in the Sea: Geology of Hawaii, 2d ed. Honolulu, University of Hawaii Press.

State of Hawaii, Department of Land and Natural Resources, July 1984, Geologic Hazards Impacts Analysis of Potential Geothermal Resources Areas. Circular C-107.

Moore, R., 1985, Hawaiian Volcanoes Observatory, personal communication.

LAND USE COMPATIBILITY

State of Hawaii, Board of Land and Natural Resources, February 25, 1983, Findings of Fact, Conclusions of Law, Decision and Order, CDUA No. HA 3/2/82-1463.

_____, Department of Land and Natural Resources, Division of Water and Land Development, August 1984, A Report on Geothermal Resource Subzones for Designation by the Board of Land and Natural Resources.